CLAIMS

1. A method of manufacturing an actuator device comprising the steps of:

forming a vibration plate on one surface of a substrate; and

forming a piezoelectric element having a lower electrode, a piezoelectric layer, and an upper electrode on the vibration plate,

wherein the step of forming a vibration plate at least includes an insulation film forming step of forming an insulation film made of zirconium oxide by forming a zirconium layer above the one surface side of the substrate in accordance with a sputtering method and subjecting the zirconium layer to thermal oxidation by inserting the substrate formed with the zirconium layer to a thermal oxidation furnace heated to a temperature greater than or equal to 700°C at a speed greater than or equal to 200 mm/min.

2. The method of manufacturing an actuator device according to claim 1,

wherein the temperature for heating the thermal oxidation furnace is set in a range from 850°C to 1000°C.

3. The method of manufacturing an actuator device according to any one of claims 1 and 2,

wherein a rate of temperature increase of the zirconium layer upon insertion of the substrate into the thermal oxidation furnace is set greater than or equal to 300°C/min.

4. The method of manufacturing an actuator device according to claim 3,

wherein a density of the insulation film is set greater

than or equal to 5.0 g/cm^3 in the insulation film forming step.

5. The method of manufacturing an actuator device according to claim 4,

wherein a film thickness of the insulation film is set greater than or equal to 40 nm in the step of forming the insulation film.

6. A method of manufacturing an actuator device comprising the steps of:

forming a vibration plate above one surface of a substrate; and

forming a piezoelectric element having a lower electrode, a piezoelectric layer, and an upper electrode above the vibration plate,

wherein the step of forming the vibration plate at least includes the steps of:

forming an insulation film made of zirconium oxide by forming a zirconium layer above the one surface side of the substrate and subjecting the zirconium layer to thermal oxidation while heating the zirconium layer up to a predetermined temperature at a predetermined rate of temperature increase, and

adjusting stress of the insulation film by annealing the insulation film at a temperature less than or equal to a maximum temperature in thermal oxidation of the zirconium layer.

7. The method of manufacturing an actuator device according to claim 6,

wherein the rate of temperature increase upon thermal oxidation of the zirconium layer is set greater than or equal to 5°C/sec.

8. The method of manufacturing an actuator device according to

claim 7,

wherein the rate of temperature increase upon thermal oxidation of the zirconium layer is set greater than or equal to 50°C/sec.

9. The method of manufacturing an actuator device according to claim 8,

wherein the zirconium layer is heated by an RTA method upon thermal oxidation of the zirconium layer.

10. The method of manufacturing an actuator device according to any one of claims 7 to 10,

wherein a density of the insulation film is set greater than or equal to 5.0 g/cm^3 in the step of forming the insulation film.

11. The method of manufacturing an actuator device according to claim 10,

wherein a film thickness of the insulation film is set greater than or equal to 40 nm in the step of forming the insulation film.

12. The method of manufacturing an actuator device according to any one of claims 6 to 11,

wherein a temperature upon thermal oxidation of the zirconium layer is set in a range from 800°C to 1000°C.

13. The method of manufacturing an actuator device according to claim 12,

wherein a temperature upon annealing the insulation film is set in a range from 800°C to 900°C.

14. The method of manufacturing an actuator device according to claim 13,

wherein a time period for annealing the insulation film is adjusted in a range from 0.5 hours to 2 hours.

15. The method of manufacturing an actuator device according to any one of claims 1 to 14,

wherein the step of forming the vibration plate comprises the step of forming an elastic film made of silicon oxide (SiO_2) above the one surface of the substrate made of a single crystal silicon substrate, and

the insulation film is formed above the elastic film.

16. The method of manufacturing an actuator device according to any one of claims 1 to 15,

wherein the step of forming the piezoelectric element at least comprises the step of forming the piezoelectric layer made of lead zirconate titanate (PZT) above the vibration plate.

17. A liquid-jet apparatus, comprising:

a liquid-jet head applying the actuator device manufactured by the method according to any one of claims 1 to 16 as liquid ejecting means.